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OIL AND GAS IN OKLAHOMA

MAYES, OTTAWA, AND DELAWARE COUNTIES

By
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NORMAN
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CONTENTS

ILLUSTRATIONS

FOREWORD

In 1917 the Oklahoma Geological Survey issued Bulletin 19, Part II, entitled "Petroleum and Natural Gas in Oklahoma." This volume was so popular that the supply was soon exhausted and for several years copies have not been obtainable.

The present Director has seen the need of a revision of this bulletin. On account of the lack of appropriations he has not been able to employ sufficient help to compile the data, and has called on some twenty representative geologists throughout the State to aid in the preparation of reports on separate counties. These gentlemen, all busy men, have contributed freely of their time and information in the preparation of these reports.

It will be understood that the facts as set forth in the various reports represent the observation and opinion of the different men. The Oklahoma Geological Survey has every confidence in the judgment of the various authors, but at the same time the Survey does not stand sponsor for all statements made or for all conclusions drawn. Reports of this kind, are at best, progress reports, representing the best information obtainable as of the date issued, and doubtless new data will cause many changes in our present ideas.

This report on the oil and gas geology of the northeastern counties of the State was prepared by Mr. H. A. Ireland, of the Department of Geology in the University of Oklahoma. Mr. Ireland spent considerable time in the field during the summer of 1929, and this report is the result of this investigation and the cooperation of geologists familiar with the area. The report contains a comprehensive statement of the problem of the granite exposure at Spavinaw, in addition to the discussion on the oil and gas development.

Norman, Oklahoma
February, 1930

CHAS. N. GOULD,
Director

OIL AND GAS IN OKLAMOMA

MAYES, DELAWARE, AND OTTAWA COUNTIES

INTRODUCTION

Considerable drilling of a scattered nature has been done in these counties for oil and gas but nothing of good commercial value has been encountered. The possibilities for gas have been proved and wells put down which had short-lived production at Mazie. Other wells drilled within the Pennsylvanian outcrop area and along the western side of Mayes county have possibilities.

The writer did not attempt to revise the earlier map made by L. C. Snider in 1915. New information is constantly being gathered which will make a revised map possible in the near future. With only a few modifications, the map as printed is the same as the earlier one. The map is based on the Pryor, Siloam Springs, Vinita, and Wyandotte quadrangles of the U. S. Geological Survey.

Acknowledgments

The writer is particularly indebted to Dr. S. Weidman of the University of Oklahoma for valuable aid in the field and for many valuable and helpful suggestions. Most of Ottawa County was worked out with his company and the writer has used items mentioned in his report of the lead and zinc district.

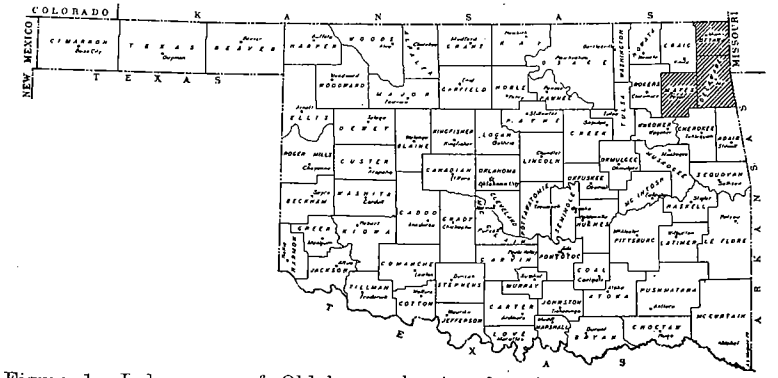

Figure 1.—Index map of Oklahoma showing location of Mayes, Delaware, and Ottawa counties.

Location and Accessibility

Mayes, Delaware, and Ottawa counties are located in the extreme northeastern corner of the State. Ottawa County borders on Kansas and Missouri, and Delaware County borders on Missouri and Arkansas. The following table gives interesting data:

COUNTY	AREA	POPULATION	PERSONS PER SQUARE MILE
Ottawa	477	41,108	86.2
Delaware	794	13,868	17.5
Mayes	676	16,829	24.9

Pryor is the county seat of Mayes County with Choteau, Adair, Spavinaw, and Locust Grove being the larger towns. This county is chiefly agricultural with timber industry in the eastern part. Spavinow Lake, formed by damming Spavinaw Creek, is water storage for the Tulsa water supply. The main line of the Missouri, Kansas, and Texas Railroad, and the Missouri, Oklahoma, and Gulf Railroad serve the county. Nearly all of the main state highways are graveled, other roads are graded, or dirt.

Jay is the county seat of Delaware County. This region is characterized by very broken topography, steep, deeply cut valleys with level prairie-like country on the divides. Most of the county is timbered and supports a very scanty population. Bernice and Grove are the largest towns. The Missouri, Oklahoma, and Gulf Railroad cuts the northwestern corner of the county and a branch line of the Frisco Railroad terminates at Grove, entering from northwestern Arkansas. Most of the main roads are gravelled and the Boone chert forms a natural hard surface for many of the secondary roads.

Miami is the county seat of Ottawa County and one of the larger towns of the state. Afton, Fairland, and Wyandotte are fair sized smaller towns. Picher and Commerce are large towns due to their location in the lead and zinc district. The main line and a branch line of the St. Louis and San Francisco Railroad and the main line of the Missouri, Oklahoma, and Gulf Railroad serve the county. All of the highways are gravelled or paved and most of the county section lines are gravelled with the chat tailings of the mine dumps. The chief occupations in this county are mining, and business. As shown by the population the county is prosperous.

Drainage and Topography

The Grand River (Neosho) is the major stream, with tributaries entering from the east and the west. It is formed by the junction of the Neosho and Spring rivers near Wyandotte. All of the western tributaries contain muddy waters due to flowing over Pennsylvanian clastic sediments. The principal creeks are Horse Creek, Cabin Creek, Pryor Creek, and Choteau Creek. The eastern tributaries are clear since they flow out of the Ozark Mountains over limestone and flint. These eastern streams are perennial spring fed streams, but the western streams are frequently dry during the summer. The main eastern branches are Lost Creek, Elk River, Honey, Spavinaw, Salina, and Spring Creeks. It is significant that Grand River flows along the western outcrop of the resistant Boone chert. Another large stream, Flint Creek, cuts the southeast corner of Delaware County.

The eastern portions of the three counties have been uplifted and since these portions are underlaid by the resistant Boone chert the uplands are more or less flat with deeply incised valleys giving a mature topography. West of Grand River the topography is a prairie underlaid by less resistant rock with outstanding buttes capped by harder rock. Along the western side of Mayes county is a scarp and highland marking the outcrop of the Bluejacket sandstone which is the surface outcrop of the lower part of the Bartlesville sand series.

The highest points of the area, about 1,200 feet, are in the southeastern part of Delaware County. The topography slopes to the north to about 800 feet and to the west to about 600 feet in western Mayes County.

GEOLOGY

The rocks of this area range from Ordovician to Pennsylvanian, the Mississippian covering the larger part. The table on page 8 shows the stratigraphic column of exposed rocks.

GEOLOGY

Spavinaw Granite

An outcrop of granite occurs about one-half mile west of the Tulsa water supply dam across Spavinaw creek in sec. 15, T. 22 N., R. 21 E., Mayes County. The strike is N. 40° E. at the northern end and N. 30° E. at the southern end of the outcrop. The granite appears in five localities as follows:

1. The granite rises out of the stream bed and extends northward to the road for a distance of about 300 feet and a width of 75 feet.

2. Another outcrop is 150 feet from the first, being 75 feet wide at the southern end and 50 feet wide at the northern end and about 125 feet long.

Surface formations in Mayes, Delaware, and Ottawa Counties.

AGE	FORMATION	CORRELATION
PENNSYLVANIAN	Cherokee shale	Allegheny
	Morrow formation (southern part)	Pottsville
MISSISSIPPIAN	Fayetteville formation Mayes limestone	Chester
	Boone chert and limestone (St. Joe limestone member)	Osage
	Chattanooga shale	Kinderhook
ORDOVICIAN	Tyner shale Burgen sandstone Un-named limestone and dolomite (Arbuckle?)	Chazy Beekmantown
PRE-CAMBRIAN?	Granite	

3. The third exposure, about 450 feet from the second, is 200 feet long and 300 feet wide. At this location there is an old abandoned quarry, with many good blocks of granite still in place. Transportation costs have prohibited development and the quarry is abandoned.

4. An exposure occurs 200 feet north of number 3, and is about 175 feet long and 100 feet wide.

5. The last outcrop, about 5 by 10 feet, is due west from outcrop number 3. Adjacent is a mineralized zone similar to the zone adjacent to the larger masses.

The total distance of the outcrop is about 1,600 feet. Copper stains of varying amounts occur in several places. A zone of intense

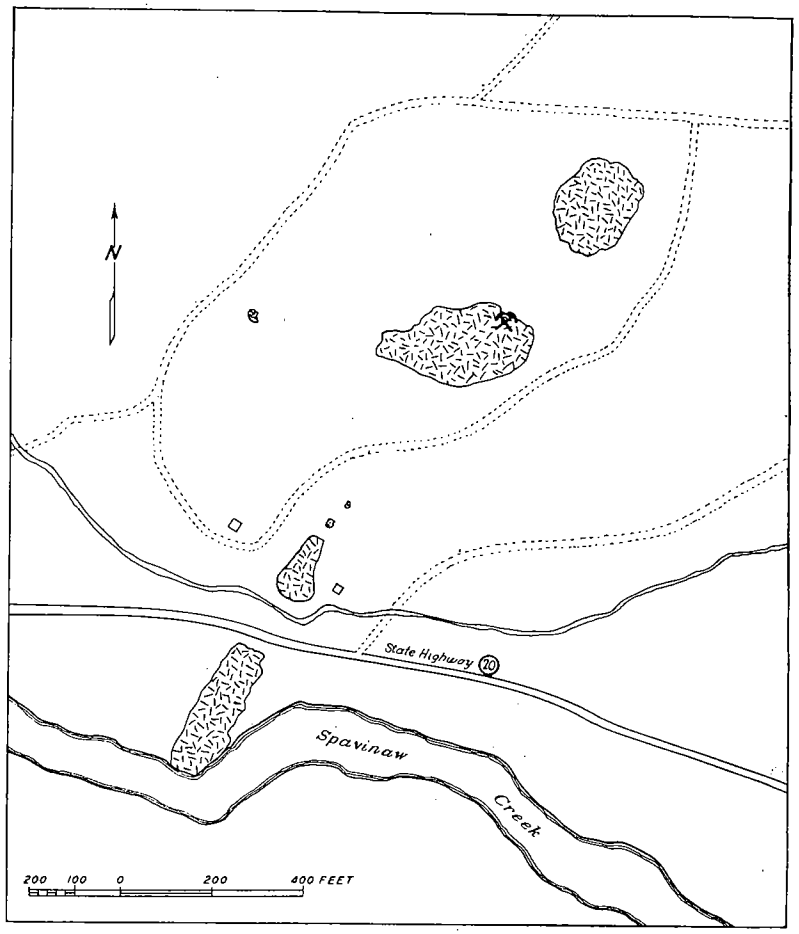

Figure 2.—Map of area of granite outcrops along Spavinaw Creek and Oklahoma Highway 20 in sec. 15, T. 22 N., R. 21 E., one-half mile west of the lake of the Tulsa water works.

silicification extends on either side of the mass, decreasing away from the granite. A well drilled on the east flank near the south end struck granite at a depth of 50 feet, 100 feet away from the outcrop. Near the north end on the same side, rotten granite was struck at 74 feet, and 200 yards east the granite was not found at 95 feet. A well a few hundred feet to the west of the granite outcrop failed to reach it at 112 feet. These wells were drilled by W. E. Kay of Spavinaw. These wells tend to show that the granite is very narrow or ridge-like in its occurrence. Immediately west of exposure number 2, a shaft 87 feet deep was sunk by the government to a nine foot deposit of pyrite to use in manufacturing sulphuric acid for use in war supplies. The shaft is now full of water and the only evidence of the shaft having encountered granite is a few weathered fragments on the dump. There are numerous pits and prospect holes dug on all sides of the granite, all of which show no commercial ore. Pyrite, dolomite, and quartz crystals are common in cavities and in veins adjacent to the igneous body.

Joints observed on outcrops Nos. 1 and 2 show very interesting features. Viewed from the end, the joints radiate fan-like. Viewed from the side they are also fan-like and perpendicular to the surface of the rock mass. When observed from the top the joints are essentially parallel with the strike of the outcrop.

The rock itself is a red, coarse-grained granite. The feldspar grains are the chief color giving constituent and are chiefly orthoclase. The grains are up to ten centimeters in diameter. Black flakes of magnetite and hornblende are scattered throughout. The quartz is not apparent to the naked eye and a megascopic examination would cause one to call the rock syenite. Examined under the microscope the rock is a distinct granite as will be described later. Some portions of the rock are green in character, especially near exposure No. 3.

The writer quotes verbatim the original microscopic description made by Dr. N. E. Drake.

> Feldspars, quartz, chlorite, and magnetite are the principal minerals of the rock, while hornblende and epidote occur sparingly. A holocrystalline texture is shown throughout the rock. The most striking and general microscopic feature is its granophyric and micropegmatitic structure. Through most of the feldspar crystals, quartz is intergrown in a most intimate manner, so that each feldspar shows radiating or alternating quartz and feldspar in each crystal, the included quartz plates or prisms show the same orientation. Quartz occurs sparingly isolated in the larger crystals, but very rarely shows its outline. Feldspars are the predominating minerals. They are principally orthoclase, but plagioclase crystals are rather common. The feldspars have a fine granular appearance and a reddish color. Phenocrysts of feldspar are quite common but they do not show crystal faces. Magnetite occurs in small opaque masses many of which show crystal outlines. They show a slight grouping through the rock and in places give a blended appearance to the crystals. The hornblende is the greenish variety and of rather uncommon occurrence. The chlorite is common and occurs in greenish bands, spherular aggregates, and minute particles. Epidote is of rather common appearance.

Chemical Analysis of Spavinaw Granite.

	Per cent
Silica (SiO_2)	71.10
Ferric Oxide and alumina (Fe_2O_3)	20.60
Calcium oxide (CaO)	2.53
Magnesium oxide (MgO)	.99
Sodium and Potassium oxides (Na_2O, K_2O)	3.76
Loss on ignition	1.11
	100.09

The following is a petrographic analysis made by Mr. Robert Roth[1] of the Indian Territory Illuminating Oil Co.

> The analysis of this rock shows it to be intermediate between an "alkali granite" and a syenite; it is in fact, much closer to a syenite than to a granite. The hand specimen shows no quartz, but a chemical analysis shows 71.10 per cent of SiO_2. In a thin section it will be noted that the quartz is present to a great extent and thus accounts for the large percentage of silica. The feldspars are largely of the soda type and are very well altered to kaolinite-like material. The ferro-magnesian silicates are largely hornblende, probably of the arfoedsonite variety, giving blue and green tones, also augite. These femics are quite well altered. The texture of the rock is hypidiomorphic, which is very characteristic of the deep-seated consolidated rocks. These characters may be found throughout and show no change in any direction. The basic secretions separating out from this "acid syenite" are composed largely of hornblende and some augite. There is no muscovite or biotite in this rock. There is some serecite present along the twinning planes of the feldspar.

Conglomerate and breccia of quartzite and chert cemented by silica is found on a wooded knoll and near a prospect hole 200 yards northeast of the last exposure of the granite. The knoll is undoubtedly a bulge with granite close beneath. Sandstone of quartzitic nature occurs in a gully on the south side of Spavinaw Creek just east of the bridge and 200 yards west of the granite. The quartzite in the conglomerate is much more indurated than the above due to silicifying solutions. In many places cavities in the silicified zone show well developed quartz, dolomite, and pyrite crystals, as well as pseudomorphs after pyrite. Jasperoid is also quite common.

The layers overlying the granite are Ordovician dolomite and limestone somewhat sandy in places. These layers are highly silicified near

1. Personal communication.

the granite and less so at a distance. The formations over the granite are seen on the south side of the creek inclined away from the crest at five to ten degree angles, the dip being the steeper on the west side. At the crest of the granite there is a definite topographic bulge which is apparently associated with the structure of the granite exposure. Other strata over the granite are the Chattanooga shale and the Boone chert.

There are two opinions as to the age of the granite. One is that the mass is a dike intruded in post-Ordovician and the other that it is a pre-Cambrian ridge.

D. D. Owens[2] first mentioned the outcrop in 1860 calling it a granitic axis, but he never visited the outcrop himself.

N. F. Drake[3] described it in detail in 1898, calling it a dike intruded into dolomite. This was the first article published by one who studied the exposure and no one has written a better description. However, he now expresses himself as differing from his original opinion. He says:[4]

> Before I knew that there was any controversy as to whether this granite was a dike or pre-Cambrian peak, I had suspected it to be the latter. I believe that the evidence is in favor of classing it as a pre-Cambrian peak.

In 1901, G. I. Adams[5] described the granite as a post-Carboniferous dike, dating the intrusion as contemporary with the folding and faulting of the Ozark uplift.

L. L. Hutchison and R. R. Severin[6] studied the outcrop and called it a dike occurring after the Pennsylvanian. The inference was made from the fact that the Mississippian rocks overlying were affected and that this region was in movement during late Mississippian and early Pennsylvanian and the dike was contemporary.

In 1907, C. E. Ciebenthal[7] refers to the granite mass as a dike.

L. C. Snider[8] in his report on northeastern Oklahoma in 1915 calls the rock a dike and gives verbatim Drake's description since the original is not easily obtained.

F. L. Aurin, G. C. Clark, and E. A. Trager[9] did not agree with the statement of earlier men and stated that the granite was a pre-Cambrian peak or ridge, but they did not present in their paper any evidence for the statement.

2. Second Annual Report of Arkansas, p. 17, 1860.
3. Op. cit.
4. Personal communication.
5. Adams, G. I., U. S. Geol. Survey, 22nd Ann. Rept., pt. 2, pp. 77-78, 1900-1901.
6. Oklahoma Geol. Survey, Bull. 2, pp. 153-153, 1911.
7. U. S. Geol. Survey Bull. 340, p. 189, 1907.
8. Oklahoma Geol. Survey Bull. 24, part I, 1915, pp. 51-53.
9. Bull. Am. Assoc. Pet. Geol. vol. 5, no. 2, p. 121 and p. 147, 1921.

Since 1921 many have visited the Spavinaw area and prominent geologists are on both sides of the controversy.

Luther White[10] presents the following as evidence for the pre-Cambrian:

> The granite at Spavinaw is not a dike. It is the granite core of an anticline. Exposure is due to uplift, overlapping, truncation, and erosion. Granite is encountered at remarkably shallow depths throughout northeastern Oklahoma, over the broad arch of the Ozark uplift. Granite is encountered on a dome at 480 feet at Inola, at Owasso at 1,365. These wells show that the exposure of granite at Spavinaw is not remarkable. The overlying rocks at Spavinaw dip away from the granite in all directions. I believe dips ranging from ten to twenty degrees may be measured around the flanks of this structure. There is a notable lack of evidence of heat metamorphism. Fossils occur in the Ordovician dolomite in a splendid state of preservation within inches of the granite contact. Also they occur in greater abundance in the contact than they do at higher stratigraphic horizons. This indicates an abundance of life at the strand line, as would be expected. The absence of a basal conglomerate is striking. This is the case, however, at nearly all places in northeastern Oklahoma where the Arbuckle limestone-granite contact has been encountered in drilling wells, on a basis of sample observation.

Mr. Fritz Aurin[11] says in regard to the trip of several years ago with Mr. Trager:

> It was our opinion that the granite was not an intrusion, but that of an old topographic feature. There is no evidence of the ordinary features accompanying an intrusion such as contact metamorphism, sills, and dikes. It was also our further opinion that the Ordovician dolomitic limestone had overlapped the granite. No sharp folding was observed either in the Ordovician or in the beds overlying the granite. There is considerable brecciation in the top of the Ordovician limestone at the contact of this formation and the overlying green shale as observed at a locality a short distance downstream from the granite outcrop. This breccia was made up almost entirely of chert and appeared to be mostly debris along the unconformable contact.

Sidney Powers[12] believes the granite to be a buried hill with the anticline superposed upon it, and compares it to numerous other anticlines of the oil fields underlain by similar hills many of which have been encountered by drilling wells.

Mr. Robert Roth[13] as a result of his studies of the granite gives the following:

> Dips of the surrounding sediments, that is in Ordovician or older are about the same as those described by Bridge and Dake in a reprint from the Missouri Bureau of Geology and Mines entitled

10. Personal communication.
11. Personal communication.
12. Personal communication.
13. Personal communication.

"Initial Dips Peripheral to Resurrected Hills". These dips are not reflected in the overlying Mississippian and are soon dissipated in the older rocks, as those at Sapvinaw dam are practically flat lying. Furthermore, there are conglomerates and quartzites adjacent to this alkali syenite (granite) which are not metamorphosed. If the igneous rock were a dike or a pegmatite one must find some of the following conditions or else it cannot be classed as such: If it were a pegmatite the adjoining limestone, dolomite, and sandstone would be intensely altered, due to the pneumatolytic action of the hydrothermal gases eminating from this igneous mass. Nothing like this is found, but we do find a great amount of grahamite, marcasite, and pyrite adjacent to the mass which with the temperatures naturally formed by the dike would not exist in this proximity. The alkali syenite shows definitely no contact phases such as a change in texture from the central portion toward the contact which is always found adjacent to dikes and pegmatite. This point is probably the best evidence, proving that this mass is but an exposed remnant of a much larger mass. Furthermore the crystalline texture of that portion which is weathered is identical with any other portion of the ridge.

C. W. Honess[14] has visited the outcrop several times and studied thin sections. He states:

To my mind after studying the outcrops, the granite must be a dike as originally interpreted, by N. F. Drake, and I give the following reasons:

1. The granite is unusual. It is a pegmatite.
2. The chert at the contact is shattered vertically to bits as if by heat.
3. There is an absence of a basal conglomerate and all other evidence of erosion at the top of the granite.
4. The cherty dolomites dip away from the granite at the rate of about five degrees dipping southeast on the southeast side and northwest on the northwest side so that the granite is at the crest of an anticline.

Dr. S. Wiedman of the University of Oklahoma believes the granite to be a dike. The evidence upon which he interprets the intrusive character of the Spavinaw granite is as follows:[15]

1. The texture of the Spavinaw granite is not that of a normal granite but is distinctly pegmatitic, the granophyritic and micropegmatitic character being the most striking feature of the rock. Pegmatites are characteristic dike rocks.

2. The extensive alteration of minerals within the granite such as the metasomatic replacement of the feldspar by epidote and sericite and the replacement of hornblende by chlorite are characteristic hydrothermal alterations and indicate a type of alteration commonly associated with contact metamorphism.

3. The Ordovician limestone along the contact with the granite is altered to chert or jasperoid, the limestone being completely sillicified within a zone of 25 to 50 feet from the contact, beyond which to about 100 feet or more silicification as well as dolomitization and the formation of pyrite has taken place. The chert along the contact is considered a metasomatic replacement of the limestone, and with the associated dolomitization and pyritization is interpreted as evidence of contact metamorphism developed at slight or moderate depths and under thermal conditions of moderate rather than high temperatures.

4. Parallel to and along the contact there is fissuring and brecciation of the jasperoid, and there is also a distinct arching of the overlying strata above the granite and these are common structural features associated with upthrusting by igneous intrusion.

5. There is no evidence of conglomerate or other distinctly clastic sediments derived from the granite along the contact and thus the character of the sedimentary rock at the contact supports the view that the granite is intrusive rather than basal to the surrounding rock.

6. The Spavinaw granite is similar in its pegmatitic texture to the intrusive pegmatic granite in the Rose Dome[16] of Woodson County, Kansas and the development of chert and other phases of metamorphic rocks along the contact with the granite in both these localities is very much alike.

14. Personal communication.
15. Weidman, S., Paper read before the Oklahoma Academy of Sciences, Oklahoma City, November 29, 1929.

In the judgment of many geologists the evidence of contact metamorphism is not sufficient to be conclusive that the granite was intruded. There are no minerals such as wollastonite, vesuvianite, garnet, serpentine, or staurolite found in the contact zone with the Ordovician dolomites. Alteration has taken place in the granite but such may have occurred previously. Quartz, pyrite, and dolomite crystals may be formed in a number of ways besides that of contact matamorphism. There is no doubt that considerable mineralization has taken place adjacent to the granite but the mineralization has not exhibited the expected high temperature contact metamorphic minerals. In some way the presence of the granite has affected the zone and if intrusion has taken place it was different form the usual type. The granite as a solid may have been pushed up into the sediments by the vertical component stress resulting from lateral pressure. Such would give the fracturing and folding described, allowing the circulation of water which deposited minerals in the existing cavities and fissures.

The Spavinaw exposure is another of the many igneous outcrops occurring in the Mississippi valley. The Rose Dome intrusion in eastern Kansas, the periditite at Manhattan, Kansas, the pegmatites and diorite sills of southeastern Oklahoma may be given to show that intrusions have occurred. In Camden county in central Missouri, there is a pegmatite dike described by Winslow[17] and by Adams.[18] The age given is post-Ordovician and perhaps post-Carboniferous.

Ordovician

The Ordovician rocks outcrop in several places within this area. About 10 to 15 feet of limestone is exposed beneath the Chattanooga shale two miles north of the mouth of Elk River in T. 23 N., R. 24 E.

16. Twenhofel, W. H., and Bremes, B., An extension of the Rose Dome intrusives, Kansas, Bull. A. A. P. G., vol. 12, p. 757.
17. Winslow, Arthur, Missouri Geol. Survey, vol. 7, p. 432, 1894.
18. Adams, G. I., U. S. Geol. Survey, 22nd, Ann. Rept. pt. 2, p. 77, 78, 1901.

The outcrop is terminated to the west by Grand River and the Seneca fault. The rock is composed of fine-grained, thin-bedded limestone with flint nodules near the river level. Near and at the contact with the shale above, the formation is dark and dirty colored with flinty portions and many pits and irregularities. The rock weathers to nearly the same color of the soil. The limestone is very dolomitic.

At Spavinaw the formation rises from stream level at the Spavinaw dam to about 200 feet above the granite mass and then dips rapidly at 5 to 10 degree angles. The whole exposure is about a mile long and is well silicified in some portions, especially over the granite. The strata here are composed of well-bedded layers of dolomite, sandy or siliceous limestone with occasional thin beds of sandstone, nearly quartzitic in texture. Flint layers and nodules weather into rounded forms. The formation also rises toward the north and at the north end of the Spavinaw dam it is 25 feet above stream level. The following is a description by Robert Roth[19] of a section made on the apex of the granitic axis:

> There is about 30 feet of sandy dolomite, some interbedded green shale, and many quartz and calcite vugs. These vugs are largely filled with grahamite or allied substances. There are very few fossils in this section. The next 20 feet contains considerable white angular and frosted sand interbedded with fine dolomite. This also contains considerable grahamite. Below this, there appears to be another unconformity as there is crumpled chert conglomerate and a great abundance of grahamite. Below this there is about 40 feet of light and dark fine-grained dolomite, quite platy in places, containing drusey vugs of quartz and chalcedony. Most of the finely plated material shows evidence of sun-cracks.

Fossils of lower Ordovician age have been found in the formation at Spavinaw and identified by R. D. Mesler of the U. S. Geological Survey at the request of Sidney Powers.

Turritoma milaniformis
Orospira bigranosa
Liospira sp?

These belong to the "Swan Creek" zone of the Cotter formation in Missouri and Yellville in Arkansas. Another group of fossils collected by Sidney Powers were identified by H. N. Coryell of Columbia University as being equivalent to Beekmantown and Chazy.

Liospira
Eotomaria
Eccylomphalus
Archinacella
Maclurites

It is reported that there is an outcrop of Tyner shale about one to two miles above the eastern end of Spavinaw lake, which would put it in about sec. 15, T. 22 N., R. 22 E. The writer has not seen the exposure and therefore can not verify the report.

19. Personal communication.

Ordovician occurs along Spring Creek near the border of Mayes County in sec. 12, T. 19 N., R. 20 E. It does not show on the south bank of the stream but rises to the northward where about 15 feet of it is found. The layers beneath the black shale are limestone interbedded with thin shale layers. This is probably an exposure of the Tyner. Farther to the south the Burgen sandstone and the Tyner shale appear at the surface and the Chattanooga shale lies over shale where in the northern exposures it overlies limestone. An outcrop just three miles out of Oklahoma into Missouri up Buffalo Creek shows limestone at the contact with four inches of sandstone, probably representing the Sylamore, between it and the Chattanooga shale.

The exposures of dolomite and limestone correlate with the Jefferson City dolomite of Missouri, the Yellville of Arkansas, and the Arbuckle limestone.

L. C. Snider[20] reports the sandstone found at the base of the Chattanooga at Flint on Flint Creek, Delaware County, to be Sylamore. The author considers the sandstone to be the Burgen. The sandstone at the base of the Chattanooga at Eagle Bluff 15 miles southeast of Flint is reddish, hard, dense, ferrugineous. The sandstone herein called Burgen is a white, medium to fine-grained sandstone with streaks of iron oxide weathered brown. The sand grains are clear quartz and well rounded, with some oblong, and some etched and frosted characteristic of Ordovician sands. Fucoids are abundant in the upper layers, some beds being entirely composed of them. The sandstone rises rapidly out of the creek bed beginning one-half mile above the bridge at the town of Flint. The strata dip away from there to the south disappearing beneath the creek bed a mile or so from the bridge. The maximum thickness shown is 20 feet near the bridge with the base not shown. It forms a bench in the valley with the Chattanooga shale above it. The sandstone rises to the west from the creek and in a half mile is 80 feet above the stream level. Luther White[21] also designates this outcrop as Burgen. It has never been mapped as such.

A well drilled five miles south of Mayes County in SW.¼ NE.¼ NW.¼ sec. 36, T. 19 N., R. 21 E., Cherokee County, gives a very fine section of Ordovician. The well starts in the Chattanooga shale and gives a section of dark limestone, reddish in the lower part, with eight shale beds 10 to 100 feet thick between layers of limestone 30 to 340 feet thick. At about the center of the section, 1,500 feet from the top, is 180 feet of grey sandstone. The whole section is 2,857 feet thick with 80 feet of Chattanooga shale and surface gravel, 2,210 feet of limestone, 377 feet of shale, and 190 feet of sandstone. In another well five miles south of Delaware County in sec. 32, T. 19 N., R. 25 E.,

20. Snider, L. C., Geology of a portion of northeastern Oklahoma: Oklahoma Geol. Survey Bull. 24, p. 21, 1924.
21. White, Luther H., Subsurface distribution and correlation of the pre-Chattanooga ("Wilcox" sand) series of northeastern Oklahoma: Oklahoma Geol. Survey Bull. 40-B, p. 7 footnote, also p. 21.

Adair County, there is 289 feet of Boone chert, 75 feet of Chattanooga shale, 1,066 feet of Ordovician limestone, some shale, and sand with granite at the base.

Chattanooga Shale

The Chattanooga shale is a thin-bedded, black, bituminous and carbonaceous shale. It weathers along joints into rectangular blocks, but on continued weathering these split into thin paper shale. The beds are uniform in composition and contain few fossils. Siderite concretions of various sizes and cone-in-cone structures occur in some localities. Fossils are found within some of the concretions. The shale is found throughout these countries at the surface and in wells. The thickness is variable up to a maximum of 85 feet. In some localities a sandstone at the base called the Sylamore occurs. Springs are very common at the top of the shale due to its impervious character, and are often an aid in locating the contact.

The exposures in Mayes County are along Spring and Spavinaw creeks. The outcrop in the southeast corner on Spring Creek extends up the stream for 12 miles, but only 2 miles of it is in Mayes County. The shale is characteristic and about 40 feet thick and underlaid by Ordovician rock, described previously. The Oklahoma geologic map shows 6 miles of Chattanooga shale along Little Spring Creek, but such is an error for no outcrops occur.

The shale is exposed in Spavinaw Creek for about 20 miles with the greater part in Delaware County. Part of it is covered by the water of Spavinaw Lake, but a complete section can be observed at the dam. The shale here measures 85 feet and rises until over the granite mass and then dips rapidly westward until it disappears 2 miles downstream. Near the highway bridge there is 50 feet of shale.

Depths and thickness of Chattanooga shale in Mayes County.

LOCATION	DEPTH TO TOP	THICKNESS
Sec. 26, T. 19 N., R. 18 E.	402	40
Sec. 23, T. 19 N., R. 18 E.	475	52
Sec. 2, T. 20 N., R. 18 E.	410	46
Sec. 8, T. 20 N., R. 19 E.	350	55
Sec. 17, T. 21 N., R. 18 E.	518	53
Sec. 1, T. 21 N., R. 19 E.	325	65
Sec. 32, T. 21 N., R. 20 E.	166	34
Sec. 9, T. 22 N., R. 18 E.	593	37
Sec. 31, T. 22 N., R. 20 E.	201	62
Sec. 2, T. 23 N., R. 21 E.	96	84
Sec. 2, T. 23 N., R. 21 E.	116	55
Sec. 2, T. 23 N., R. 21 E.	120	40

In the southeast corner of Delaware County the shale is exposed for 5 miles along Flint Creek. The outcrop extends to the juncture of Illinois River and Flint Creek and into Cherokee County nearly to Tahlequah. The base of the shale is shown at Flint and is about 50 feet thick with 20 feet of Burgen sandstone exposed beneath. The shale is also along Spavinaw Creek in Delaware County. Two small outcrops occur on Drowning Creek a mile from its juncture with Grand River. At Armstrong Ferry in Sec. 24, T. 24 N., R. 22 E., the south member of the Seneca fault brings up a small exposure of about 10 feet of Chattanooga shale. One other exposure occurs in Delaware County, on the south side of Grand River below the mouth of Honey Creek near the center of T. 24 N., R. 23 E. Here the shale is 80 feet thick with the base not exposed.

Only one outcrop of the shale occurs in Ottawa County. It is about a mile north of the county line in the southwest corner of T. 26 N., R. 24 E. Here it is 25 feet thick and shows the base above 15 feet of Ordovician limestone.

The thicknesses in closeby localities not in the counties of this report are as follows: 20 feet on Buffalo Creek three miles in Missouri, with Ordovician below; 50 feet at Southwest City, Arkansas; 60 feet northeast of Tahlequah; 40 feet on Clear Creek five miles south of Mayes County line; 40 feet on Cabin Creek one mile north of the Mayes County line.

All of these exposures are inliers. The broad uplift of the Ozark region has bowed the rocks up in Mayes and Delaware counties. The shale is near the surface in all major stream valleys and shows in some of them as outlined above. It would not require much cutting to reach the shale in other localities. In northern Ottawa County the wells show the shale to be 450 to 500 feet down and from 0 to 30 feet thick. (See the table of wells of Ottawa County).

The Chattanooga shale is found in nearly every well that is drilled to its horizon in eastern and northeastern Oklahoma. It is found near Tulsa, Okmulgee, Seminole, Oklahoma City, and thence to where it outcrops again in the Arbuckle Mountains. Much discussion has occurred as to whether the shale is Mississipian or upper Devonian and there still will be. But it is generally accepted now in most places as being lower Mississippian, rather than Devonian. This puts it just below the Kinderhook shale of the Mississippian type section. The shale may be correlated with the Woodford chert of the Arbuckle Mountains, the Noel shale of Arkansas, the Chattanooga shale of other places in the Mississippi Valley, and the upper part of the Ohio shale.

The fauna includes some linguloid brachiopods, many conodonts, shell fragments, and an occasional form of pelecypod or other form in the interior of small concretions. Remains of Dinicthys are sometimes

found. A plant spore, *Sporangites huronensis* is a good marker of the Chattanooga.

Kinderhook Shale

In nearly all places where the top of the Chattanooga shale was observed there was a foot or so of greenish-black soft shale between the black shale and the overlying St. Joe limestone member of the Boone chert. This layer is thicker to the south in Cherokee County and to the west in western Mayes County. This shale is the representative of the Kinderhook which overlies the Chattanooga in the type section.

Boone Chert

The Boone chert is typically a formation of alternating limestone and flint layers. Practically the eastern half of this area is underlaid by the chert, forming hills, incised valleys, and bluffs along streams giving a rugged topography everywhere characteristic of the Ozark Mountains. The chert weathers into sharp angular fragments which, mixed with soil, forms a thick covering. These fragments make it difficult to walk when on slopes. The type locality is in Boone County, Arkansas.

The Boone is separated from the Chattanooga shale by the soft green layer mentioned previously and several feet of thin uneven-bedded soft limestone with no flint and which weathers whitish. This limestone is called the St. Joe limestone and designated as a member of the Boone. Its type location is at St. Joe, Arkansas, and it correlates with the Fern Glen of Missouri.[22] In southern Ottawa County the limestone is 15 feet thick with a shale parting of three or four inches of soft blue shale 5 feet above the base. At Spavinaw an excellent outcrop 20 feet thick occurs on the hillside a few hundred feet below the dam:

Section of St. Joe limestone near Spavinaw Lake dam.

	Feet
Thick to medium bedded dense gray limestone	9
Shaly layer with 6 inches of soft blue shale	1
Finely uneven thin bedded limestone	10

Along Spring Creek the St. Joe is 11 feet thick and resembles that of elsewhere. At Flint the limestone is 15 feet thick on the east side of the creek. A mile west of Flint the bed is 8 feet with the transitional shale below not typically greenish. A half mile east of Eucha on Spavinaw Creek at a spring there is 18 feet of St. Joe as follows:

22. Girty, G. H., Faunas of the Boone limestone at St. Joe, Arkansas: U. S. Geol. Surv., Bull. 598, 1915.

Section of St. Joe limestone east of Eucha.

	Feet
BOONE CHERT	
St. Joe member	
Limestone	10
Soft greenish shale	6
Hard thick bedded limestone	2
CHATTANOOGA SHALE	

In well records there is often shown a stratum of soft non-flinty layer at the base of the Boone which is probably St. Joe.

The lower part of the Boone contains light colored flint and more limestone than the upper part. The chert layers are generally persistent as a stratum and uniform in thickness giving a well bedded appearance. The cherts are more porous and darker in color, weathering frequently with considerable iron oxide stains. In northern Ottawa County about 110 feet from the top is a "green limestone" layer more or less persistent and just below it a brown lime oolite layer called the Short Creek member, which are very useful in correlation in wells. Because of the similarity of the successive layers of chert and limestone it is difficult to locate ones place in the Boone section, and these above mentioned layers are valuable. The Boone is more or less pervious to water and many springs are found at the base of the formation where ground water flows out upon the impervious Chattanooga shale.

The thickness is uniform in northern Ottawa County, being 320 to 390 feet in wells. (See table of wells in Ottawa County). The thickness diminishes to the west away from the border of the Ozark uplift. In the northeast corner of Mayes County the Boone is 101 feet as shown by a well. A well on sec. 17, T. 21 N., R. 18 E., the western border of the same county, shows the Boone 64 feet thick. In the same well occurs 8 feet of St. Joe and 9 feet of green shale known as Grass Creek shale[23] which is the same as the few inches of green shale overlying the Chattanooga shale in various places.

Due to the Ozark uplift there was considerable fracturing and a certain amount of faulting. Later these fractures were cemented together by silica and formed widespread areas of breccia composed of flint fragments. This is especially true in the lead and zinc area of northern Ottawa County. Also, one happens upon a fissure now and then which has a breccia silicified together in it. An example is the one at Armstrong Ferry at the west landing.

The Boone chert is Osage age including the Fern Glen, Burlington, Keokuk, and lower Warsaw. It represents the lower part of the "Mississippi lime" of the driller.

23. Woodruff, E. G., and Cooper, C. L., Geology of Rogers County: Oklahoma Geol. Survey, Bull. 40-U, p. 13, 1928.

Chester Series

The Chester formations of northeastern Oklahoma are the Pitkin limestone, the Fayetteville shale, and the Mayes limestone. The formations are very variable in thickness and lithology, lensing out and thinning to the north. The Pitkin limestone is not found in these counties but is found not far from the southern border of Mayes County. The Mayes and the Fayetteville will be discussed together as they are closely related and the contacts are indistinguishable in most places.

The name Mayes was given by L. C. Snider[24] because of the best development of the limestone in Mayes County. The Fayetteville shale takes its name from the type locality at Fayetteville, Arkansas. The Mayes formation is considered as the limestone immediately overlying the Boone chert and beneath the black shale and limestone of the Fayetteville. In the southern part of Mayes County, sec. 15, T. 19 N., R. 19 E., the Mayes is 50 feet thick with about 50 feet of Fayetteville capped by the Morrow formation. A very fine exposure of the Mayes, 97 feet thick, occurs two miles northwest of the above location on the west bluff of Grand River. The section consists of thin-and heavy-bedded fossiliferous limestone interbedded with black shale and capped by the Morrow. North of this point, about the vicinity of Pryor, the Mayes is about 100 feet thick. It thins to 30 or 40 feet at the northern boundary of the county. The limestone near Pryor is a granular, crystalline, crinoidal or coquinal dark colored limestone. It forms a flat prairie with a few feet of soil cover with occasional broad places where the soil has been washed away. East of Pryor are a number of hills of Boone chert projecting through the Mayes limestone and farther east in the area of the Boone outcrops. One of these hills is one-half mile east of Pryor and several others are to be found 6 miles east along the main highway. These have been explained[25] as islands of Boone around which the Mayes was deposited, since the Mayes is unconformable on the Boone. Even though they are of small extent, several hundred yards to one-half mile in length, it is possible that they are results of uplift. There is no evidence of strand features around the base of the hills so it is thought that they may be results of subsurface movement. The one near Pryor is fractured with Mayes on the west side apparently faulted with a small fault against the Boone. All of the beds are tilted at this point.

A fine section of the Mayes may be seen in a stream along the highway to Locust Grove from Choteau, about two miles east of the bridge over Grand River. Here the Mayes is in contact with the Boone and shows a thin platy limestone, shaly at the base, with heavy limestone above. Above this is limestone and shale followed by the thin white-weathering limestone of the Fayetteville. All of the limestone east of Grand River presents a similar appearance, which may be seen in the railroad cuts and along the major stream valleys.

24. Op. cit., p. 27.
25. Op. cit. p. 26.

The Fayetteville in this region and 5 miles to the north is primarily a thin-bedded, two to five inches, drab, dense limestone with some interbedded shale, and weathering into whitish cubical and angular fragments. Above this is a thin black shale about 20 to 40 feet thick. In places where erosion has not removed it, there is an upper limestone. On the outlier in sec. 31, T. 21 N., R. 20 E., the Morrow overlies the shale. Several other buttes southeast of Pryor give excellent exposures on this phase of the limestone of the Fayetteville.

To the north of Pryor, the Fayetteville thins and changes in character. The shale becomes grey rather than black, and above is thin platy earthy limestone very fossiliferous. Below the shale is a thin bedded limestone resembling that farther to the south. This character is especially well shown east and southeast of Adair about four miles.

In southern Ottawa and northern Delaware counties the Fayetteville is similar to the formation in northern Mayes County. The northernmost outcrop is a small conspicuous knoll of earthly and platy limestone a half-mile southeast of Fairland. To the north of this point the formation has been removed by erosion, and the Cherokee formation overlies the Mayes limestone.

Along Rock Creek, secs. 32 and 33, T. 23 N., R. 20 E., the Mayes is well exposed, about 40 feet being present. The lower part is thin platy limestone with a layer of yellowish sandstone above followed by more limestone, all being more or less fossiliferous. Other outcrps in this region are of the same character. In northern Delaware and Ottawa counties, the Mayes is variable, having considerable sandstone interbedded with thin fossiliferous limestone. The lower part is dark crystalline crinoidal or siliceous limestone. These variable beds are most common in the area around Grove and in eastern Ottawa County where outliers of the Mayes occur. Near Berenice the Mayes is about 20 feet thick. In northern Ottawa County the top of the Mayes is sandstone with shale below and followed by a compact coquina limestone. The top of the Mayes in this region generally has a layer of gravel at the top. The sandstone increases in thickness from south to north. The shale is a lateral grading of an upper part of the formation, but the limestone is rather persistent in character, though not in thickness, from Choteau to the Kansas line.

The sandstone occurs on top of a hill two miles east of Miami where it has abundant bryozoa of the type Archimedes. The sandstone and shale measure 20 feet with 25 feet of crinoidal fossiliferous limestone below. In the western part of sec. 31, T. 29 N., R. 24 E., a sink-hole due to caving of an old lead and zink mine shows Boone

chert at the bottom in contact with the Mayes. There is 24 feet of heavy bedded limestone with soft, buff, fossiliferous sandstone at the top, but no shale is present. Fifty feet into Kansas across the border of sec. 17, T. 29 N., R. 24 E., is another larger sink showing the contact of the Boone with the Mayes, and a section as follows:

Section of Mayes limestone 50 feet north of sec. 17, T. 29 N., R. 24 E.

	Feet
MAYES	
gravel	
Cream colored shale	5
Soft buff medium grained sandstone	5
Gray-black shale	50
Coquina limestone	30
BOONE	

This same sandstone with gravel on top is found on a hill one mile south of Baxter Springs, Kansas. Below it is shale and the coquina limestone of the Mayes. The possibility of the sandstone being Cherokee is discarded because of the presence of the gravel. No similar fossiliferous sandstone is found in the Cherokee formation. A preliminary study of the fossils of the sandstone show them to be Mississippian. Four miles east of Spring River between secs. 2 and 11, T. 28 N., T. 24 E., the same fossiliferous sandstone occurs over the limestone of the Mayes formation.

It is noteworthy that in northern Ottawa County and also in the vicinity of Pensacola, gravel occurs on the hills and in the valleys with the Mayes formation always underlying. The pebbles will average about an inch in diameter and are generally well-rounded or subangular and composed of flint with a brown outside stain. Portions of the Mayes limestone are silicified in the lead and zinc district and flinty pebbles may well have been derived from such localities as well as from the abundant flint layers and nodules of the Boone chert. These pebbles were reworked out of the Mayes and Boone and laid at the base of the Cherokee. The gravel does not occur within the area of Cherokee exposures. Just west of the city limits of Miami the gravel is bound together with asphalt. Above the gravel is the yellowish oxidized shale of the Cherokee and below the thin shale and coquina limestone of the Mayes. East of Miami, along Tar Creek, gravel is embedded in a ferruginous sandstone with coquina limestone and thin platy sandstone above showing that one source of the gravel is the Mayes. Pebbles are also found in the Mayes in northern Mayes County. The gravel has been described as occurring in shafts of lead and zinc mines. Both surface and subsurface occurrences have been described in the Oklahoma Geological Survey bulletin on the lead and zinc district by Weidman.[26]

26. Weidman, S., report now in maniscript form.

Siebenthal[27] noted the gravels and called them Tertiary and allied them with gravel of the Atlantic coast and Mississippian embayment. If Tertiary they would probably be of river or lacustrine deposition and would have about the same elevation. Where the Cherokee contact occurs at the base of the hills there is gravel and as well where the contact occurs on the top of a hill. The gravel may therefore be used to define the top of the Mississippian.

The map by Snider derived from the earlier one by Siebenthal shows the Chester or Mayes formation as terminating in northern Ottawa County. The Mayes is found in contact with the Boone chert north of Baxter Springs, Kansas, and it has been found in sinkholes within the area mapped as all Boone, so that the Chester formations should be extended into Kansas.

The thickness of the Mayes is well known in Ottawa County because of the many prospect holes drilled through it in the lead and zinc district and by wells drilled for water in other areas. The thickness is from 20 to 50 feet with an average of 37 feet.

The Fayetteville shale can be correlated with the Caney shale of southern Oklahoma and with the middle and lower upper Chester of the Mississippi Valley. The Mayes contains Batesville and Moorefield faunas. The southern part of the formation has a fauna typically that of the Moorefield and it dies out to the north as the Batesville becomes more prominent. In as much as the northern part of the Mayes is sandstone and the Batesville fauna increases to the north the correlation with the Batesville sandstone of Arkansas become logical.

Morrow Formation

The Morrow formation is the lowest of the Pennsylvanian series of rocks. It occurs over the Chester and is found only in the southern part of Mayes County, thinning out to the north. The northermost outcrop is in the Seneca fault block two miles south and one-half mile east of Pryor, in and along a small creek and the road-side gully. The rock is a thin platy, irregular bedded, fucoidal and arenaceous limestone. East of the fault plane and higher than the limestone is a layer of sandstone with the typical limestone of the Fayetteville above. Just where the south member of the fault crosses is not definite, but it probably cuts through between the sandstone and the Fayetteville. Another outcrop is reported within the Seneca fault block in sec. 15, T. 22 N., R. 20 E. This location has much sandstone and cannot be definitely called Morrow. It is also much farther to the north than the last outlier of Morrow eight miles away. This outlier is formed by the Morrow as a cap to the hill and is located in sec. 31, T. 21 N., R. 20 E. The Morrow here is 35 feet thick, 20 feet of dark earthy cross-bedded sand-

27. Siebenthal, C. E., and Smith, W. S. T., Joplin district, Missouri and Kansas, U. S. Geological Survey Folio no. 148, 1907.

stone above 15 feet of thin, platy, earthy, and heavy bedded limestone. The Morrow here overlies the black shale and typical whitish limestone of the Fayetteville. To the southward the Morrow becomes more calcareous losing the sandstone bed and the thin platy character. The thickness of the Morrow just south of Mayes County is about 100 feet. In the well in sec. 17, 21 N., R. 18 E., the formation is 120 feet thick.

In sec. 16, T. 19 N., R. 19 E., there is only 5 feet of sandstone with 15 feet of platy crinoidal limestone above, belonging to the Morrow.

Cherokee Formation

The Cherokee formation occupies the western two-fifths of Mayes County and the northwestern one-third of Ottawa County. No Cherokee occurs in Delaware County except for small areas within the downthrown block of the Seneca fault. Numerous outliers of the Cherokee occur to the east of the major outcrop, some as much as five miles. These are generally elevations capped by a hard layer of sandstone. A broad level prairie exists where the formation outcrops except for the outliers and the upland underlaid by the Bluejacket sandstone member.

The Cherokee measures 450 to 500 feet at the Kansas line and thickens to the south. Near Pryor it is about 1,000 feet. Only the lower portion is exposed in these counties. The formation is composed primarily of shale, with frequent lenticular and variable beds of sandstone, and occasional limestone layers. The shale is thin bedded, soft, and often clayey, varying in color from blue-grey and brown to black. Thin layers of coal occur, particularly about 20 feet beneath the Bluejacket sandstone. Openings have been made and considerable effort spent but coal of value has not been worked in these counties. In Craig and Wagoner counties the Bluejacket coal is mined. This formation is the chief oil and gas producing horizon of the proven fields in adjacent counties.

The Bluejacket sandstone is an outstanding member of the Cherokee formation. It is the surface outcrop of the Bartlesville oil sand. The sandstone appears as a scarp and as the cap rock on buttes and outliers in the western part of Mayes County. Four miles west of Pryor on the north side of the highway the sandstone is 58 feet thick, 38 feet being a massive bluff.

Section of lower Cherokee west of Pryor.

	Feet
CHEROKEE	
Thin sandstones and shales	15
Dense, dark, bluish, fossiliferous limestone, several beds 2 to 3 inches thick	1
Sandy shale	5
Friable, buff, massive, crossbedded sandstone, some iron concretions (Bluejacket sandstone)	58
Dark colored shale with thin coal seams	110

The Burgess sand, an oil sand within the Cherokee occurs about 200 to 325 feet below the Bluejacket. The sand, being soft and friable, erodes easily and surface outcrops rarely are seen. The following is a section of the Cherokee taken from the bottom contact about a mile east of Pryor to the top of the Bluejacket sandstone. The Burgess occurs 196 feet below the Bluejacket in this section.[28]

Section of lower Cherokee east of Pryor.

	Feet
CHEOKEE	
Bluejacket sandstone	
Sandstone, medium-grained massive	14
Sandstone, shaly	8
Sandstone, massive, medium-grained	37
Limestone, argillaceous, fossiliferous	8
Shales and sandstone, alternating	70
Shale, arenaceous	70
Sandstone, gray, fine-grained	7
Shale, carbonaceous, capped by 6 inches of ferruginous siliceous limestone	3
Shale, bluish	35
Limestone, argillaceous, heavily bedded, fossiliferous	3
Burgess sandstone	
Sandtone, shaly	3
Sandstone, massive, medium-grained	17
Shale with a few interbedded sandstones	135

The Bluejacket sandstone appears in the extreme northwestern corner of Ottawa County, but does not form a scarp. North of Picher one-half mile into Kansas, sandstone about 25 feet thick occurs on top of a hill known locally as Blue Mound. The sandstone is ferruginous, medium-grained, and contains considerable boggy limonite. This layer is the same as the Bluejacket. It dips three to five degrees to the northwest and is found 25 feet below the surface in the Miami syncline one mile away. At the base of the Cherokee in Ottawa County is a few feet or a few inches of gravel which is very helpful in determining the basal contact, as described previously.

The Cherokee overlies the Morrow formation to about the center of Mayes County, it overlies the Fayetteville in the northern part of Mayes County, and in Ottawa County it overlies the Mayes formation.

GEOLOGIC HISTORY

The geologic history of Mayes, Delaware, and Ottawa counties is bound up in the movements relating to the Ozark Mountains. The sediments were laid down at intervals during times subjected to repeated fluctuations causing alternate land and sea area. The land mass eventually became the Ozark Mountains and the progression to the present status furnished the origin of the sediments around it by the erosion of previously deposited strata.

28. Ohern, D. W., Unpublished manuscript of the Oklahoma Geological Survey.

Not until Ordovician time did the sea advance over the pre-Cambrian land mass designated as Ozarkia. The rocks laid at first were sandstones and dolomitic limestones about 500 to 3,000 feet thick compared to the 8,000 feet of Arbuckle limestone in the Arbuckle Mountains. If similar amounts were deposited considerable erosion has removed the Ozarkian section. It is more probable that the basin was shallow and the source of sediments limited. The white, clean, well-rounded grains of the Burgen sandstone show near shore conditions with the land mass low so that mud and silt were not brought in. After the deposition of the green shale and sandstone of the Tyner formation uplift and erosion occurred in these counties which lasted until Mississippian time. To the south, however, withdrawal did not prevent the deposition of the St. Clair marble of Silurian age, or the sea reinvaded locally. There is no Devonian unless the Sylamore be considered as such.

In Mississippian time the sea again flooded the area and the Chattanooga shale was deposited over the truncated lower Paleozic beds. This feature is well shown on the map by Luther White.[29] The shale was thin but universal over much of eastern United States. At the base the Sylamore sandstone was deposited but it occurs only locally as a basal bed. The black shale derived its carbonaceous matter from vegetation accumulated on a land mass exposed since Ordovician. An unconformity marks the top as well as the bottom of the Chattanooga shale. In some places the shale is entirely eroded but the persistence of the formation over eastern United States, though relatively thin, is remarkable. The advancing sea reworked the Chattanooga and deposited a foot or so of thin greenish shale black in some places and then deposited limestone. The topography was low at the end of Chattanooga time so that the sea had only to rework the few feet of mantle rock and deposit the Kinderhookian, resulting in clear water for the normal deposition of limestone.

The St. Joe limestone marks the readvance of the sea which lasted throughout the Fern Glen, Burlington, Keokuk, and lower Warsaw, representing the Boone deposition. Uplift caused the removal of the sea with an unconformity representing upper Warsaw, Salem, St. Genevieve, and St. Louis time. The Mayes formation and the Fayetteville indicate the return of marine waters during Chester time with the sediments containing more detritals than previously. These detritals were probably due to minor oscillations of the Ozark region preceding the widespread uplifts of the Pennsylvanian. Evidently the shore line of the Chester sea was close to where the outcrops exist today. Such is indicated by the sandy and clastic character of the deposition in northern Delaware and Ottawa counties. The source of the sediments was from the Ozark land mass which had attained considerable size by the

29. White, Luther H., Subsurface distribution and correlation of the Chattanooga ("Wilcox" sand) series of northeastern Oklahoma: Oklahoma Geol. Survey, Bull. 40-B, 1926.

close of the Mississippian as Chester deposits are chiefly around the border of the Ozarks. The Chester thins to the north and the Mississippian is marked at the top by an unconformity.

The lowest Pennsylvanian, the Morrow formation, is bounded above and below by unconformities. It thins out to the northward and allows the Cherokee to overly the upper Mississippian. The Ozark region was in oscillation throughout the Paleozoic and the movement culminated with a general warping of the rocks in the Pennsylvanian, at which time gentle folds were formed and the Seneca and Locust faults occurred.

STRUCTURE

The strata dip away from the core of the Ozark Mountains, the western border of which is in northeastern Oklahoma, so that in the counties discussed the rocks dip northwest, west, and southwest. The dip is very slight about 25 to 50 feet per mile, though it may be much steeper locally. The structure as a whole is a great broad dome-shaped uplift warped locally by minor folds with low angle dips. Major faults and a few minor faults occur.

In the eastern part of these three countries, in the Boone chert area, it is difficult to trace the structures since the Boone lithologically is so similar that definite horizons cannot be defined. Many folds and faults are thus lost to observation. A thorough examination and study of the beds would no doubt yield correlating evidence, but the time necessary for such is prohibitive. Only where the lower beds are exposed is it possible to define the structure.

A large fold occurs in southern Mayes County dipping west rapidly into the basin containing the Mid-Continent oil fields. It is interrupted east of Grand River by the Locust fault which brings Boone chert to the same level as Cherokee shale. To the east of the fault another anticline or a continuation of the above one rises along Spring Creek, with the crest unknown but probably about five miles to the northeast. Outcrops of the Chattanooga shale and the Ordovician below are found on the southern limb.

A well defined structure occurs along Spavinaw Creek with the crest of the northwest-southeast axis over the granite. The strata rise to the northwest at an angle of about three degrees and then dips away from the granite at about ten degrees to the northwest. The structure also rises to the north at a similar rate, the crest being a few miles away with the Chattanooga shale outcrops on Drowning Creek on the north limb. The disappearance and reappearance of the Chattanooga shale near Eucha shows a second large anticline on Spavinaw Creek to the east of Eucha. The fold extends for about eight miles, as shown on the map.

The folds on Spavinaw and Spring creeks bring up Ordovician rocks but the anticline along which Salina Creek flows does not show the Ordovician nor even the Chattanooga shale. All three of these folds are not noticeable west of Grand River and the strata dip uniformly westward as the Prairie Plains monocline.

Flint Creek is crossed by a fold but the direction of the axis is hard to determine. From near the stream level the Burgen sandstone rises to the west for one-half mile and then dips and disappears some distance on. On the other axis the sandstone rises out of Flint Creek about one-half mile north of the town of Flint and dips under the stream again about three-fourth mile south of town. The highest part of the structure is at the town of Flint.

The Horse Creek anticline and the Seneca fault are the most outstanding structures of the area. The anticline begins near where Cabin Creek enters Mayes County and trends northeast across northwestern Delaware County near Berenice. Near the mouth of Elk City the trend changes to almost east and continues on into Missouri. The anticline is an asymmetrical fold with the steeper side on the south. Debris has been washed down obliterating good exposures but dips of five degrees were obtained east of Tiff City. West of Berenice the dip is 15 degrees to the southeast. These agree approximately with Siebenthal's[30] description though the writer did not visit the gap cut by Horse Creek where Siebenthal measured a dip of five degrees. The dip to the north is less than five degrees dipping gently toward Afton and Fairland. An exposure of Chattanooga shale and Ordovician limestone is brought up along Grand River as the core of the anticline but it is faulted out on the west side of the river by the Seneca fault. The Grand River cuts across the anticline along the Seneca fault.

The syncline to the south of the Horse Creek fold is just as pronounced as the anticline, especially at Berenice. (see the cross-section). Elk River flows along the axis of the syncline and is therefore designated as the Elk River syncline. The strata rise again to the south as the north limb of the Spavinaw anticline.

A small synclinal fold called the Miami syncline with a northnortheast trend occurs about a mile west of Commerce, Cardin, and Picher.

The Seneca fault originates near Spurgen, Missouri, passes through Seneca, Missouri, and thence across southeastern Ottawa County, northwestern Delaware County, and diagonally across Mayes County. It apparently ends three miles south of Pryor since the soft sandstone and shale of the Cherokee formation do not give evidence of the fault trace but the trend of the fault may be continued until in northern Wagoner County near the Verdigris River the offset of the

30. Siebenthal, C. E., U. S. Geol. Survey, Bull. 340, p. 198, 1907.

Bluejacket sandstone for a mile or so indicates the fault. The greater part of the fault is double, letting down a graben, but south of Pryor Creek and along the rest of the fault there is only a single displacement. For thirty miles from where the fault enters Oklahoma, the Chester formations are let down into the Boone chert. South of this point the Cherokee shale lies within the block except for four miles of Chester near Strang. Judging from this vicinity and from the region near the southeast corner of T. 22 N., R. 19 E., the throw of the fault is about 100 to 200 feet. The fault intersects the meanders of Grand River fifteen times and many good exposures may be seen along the bluffs.

Siebenthal[31] stys:

> The width of the down dropped block ranges from 200 to more than 1,500 feet, the fault ranges in character from a simple pair of opposed breaks with the downdropped block between them, and with the strata of the wall rock on either side dipping more or less steeply toward the faulted block, to a sort of faulted syncline, the limbs of which are made up of distributive faults with the accumulated downthrow toward the axis of the syncline. The best view of this is shown on the west bluff of Grand River opposite the mouth of Elk River. Here the south limb dips from two to five degrees north increasing toward the axis, and shows four distinct dislocations, one being opposed to the other three, but leaving a resultant throw of 14 feet to the north. On the north side there is a faulted zone 55 feet wide in which there is an upthrow of 18 feet. But this is more than counter-balanced by three small faults, and by one with a throw of 22 feet to the south, and by the southerly dip of eleven degrees near the fault and two degrees some distance away.

At Armstrong's Ferry in sec. 24, T. 24 N., R. 22 E., Chattanooga shale is exposed at river level on the upthrow side of the southern fault plane. The fault may be seen in the bluffs. A hundred yards to the south a fissure may be seen across the road down to the ferry which has breccia cemented by silica. This probably represents a minor fracture accompanying the fault zone with the fragments cemented later.

Snider[32] reports two minor faults of small extent and displacement, one in the southern part of sec. 16, T. 19 N., R. 19 E., and the other in the eastern part of sec. 6 of the same township.

The Locust fault begins south of Locust Grove and extends southward into Wagoner County. The west side of the fault is the downthrow side, and causes the upper part of the Boone chert on the east side of the fault to be at the same level as the Pennsylvanian formation on the west side of the fault. This gives a displacement of somewhere between 100 to 200 feet. This fault interrupts the fold originating west of the river as described before. The displacement increases along the fault to the south.

31. Siebenthal, C. E., U. S. Geol. Survey, Bull. 340, p. 197-198, 1907.
32. Op. cit. p. 57.

OIL AND GAS PROSPECTS

The prospects for oil and gas in these counties is slight, except in Mayes County. To the west and to the north in Rogers and Craig counties oil and gas are recovered from shallow depths of 400 to 700 feet. The production is from Pennsylvanian sands, the Bartlesville and the Burgess. These formations outcrop at the surface in western Mayes County and in the extreme northwestern corner of Ottawa County. In Mayes County no production can be obtained from the Bartlesville except in the extreme northwest corner. The sand must dip beneath the overlying rocks in order to have a cover rock and the dip is not rapid enough to give that condition except in the northwest corner. In sec. 4, T. 23 N., R. 18 E., a number of wells were drilled in 1920, one of which produced five barrels of oil. The Bartlesville sand was encountered at depths from 90 to 100 feet and the Burgess sand at depths of 350 to 360 feet with intervals between of 227 to 332 feet. The depth at which the sands would be found would increase to the west. No outcrop of the Burgess was observed, but it should be found one to three miles west of the Missouri, Kansas, and Texas railroad.

Most of the production has been gas, and such is the production in the shallow pools of adjacent counties. Gas wells were drilled near Mazie in southern Mayes County but the supply soon diminished. Production varied from 50,000 to 2,000,000 cubic feet per day. One of the wells had an initial production of 175 barrels of oil. South of Inola in Rogers County there is gas in sufficient quantities to supply adjacent small towns.

Numerous wells have been drilled over Mayes County with frequent good showings of gas and oil but none have been in sufficient quantities for commercial production. Gas seeps occur in the Boone chert and several wells drilled as tests but none have produced to date. Farther to the west equivalents of the Boone have good producing horizons.

It may be said therefore, that the presence of so much oil and gas showings should indicate the presence of larger accumulations. However, the presence of such is only the prophecy of the greater accumulations to the west. One cannot expect to find large amounts of oil but small paying quantities are present which may yield returns if it is not necessary to drill too deep.

East of Grand River within the area occupied by the Boone chert a series of good reservoir sands in the Ordovician occur below the Chattanooga. However, these sandstones always contain water and any oil present has been flushed out. This applies for all three counties. The water wells of a number of the towns are drilled to the Ordovician sand generally a part of the St. Peters or Burgen. The

above eliminates eastern Mayes, all of Delaware, and eastern Ottawa counties. Structures are present, reservoirs are present, and the source of oil was probably present but what oil did accumulate is now gone.

The Sylamore sandstone which is found locally beneath the Chattanooga shale is the Misener sand of the oil field. Production is possible from it but since its occurrence is not widespread or defined, the possibilities of encountering it in wells is a gamble.

Some evidence of petroleum is found in Ottawa County. Wells have been drilled 550 to 1,045 feet into the Ordovician in the northern part of the county but the sands produce only water. Asphalt which has accumulated on the floor of lead and zinc mines near Picher is collected. The asphalt drips down from fissures and through core drill holes. These deposits do not occur except where the surface rock is Cherokee shale. The deposits are found in many places, but in only a few spots in any large quantities. In one location the asphalt accumulates at the rate of 35 to 50 barrels per month. This material is utilized by the Picher Roofing Company to make a high grade roofing compound. The collection is due to gravity and seepage and to the fact that the ground water has been drained away by the mine stopes. The origin of the asphalt is from a residue of evaporated and naturally distilled petroleum. Tar Spring on Tar Creek, six miles north of Miami, is so named because of a heavy bitumen which occurs at the base of the Cherokee shale. Deposits are also noted at the base of the shale in the gravel layer just west of the city limits of Miami, and just west of Afton. These bituminous depositions indicate the former presence of petroleum and are prophetic of the productive oil fields farther to the west and south.

The above wells have been drilled in northern Ottawa County for water or to test for lead and zinc deposits. The detailed logs may be found in the bulletin on lead and zinc now in preparation by Wiedman. Many wells occur which are not listed here.

The subsurface section of western Mayes County is well described in a sample determination of a well in NW.¼ NE.¼ NE.¼ sec. 17, T. 21 N., R. 18 E. by F. A. Bush.[33]

33. Bush, F. A., Personal communcation in Oklahoma Geol. Survey Bull. 40-U, pp. 11-13, 1928.

Table showing the thicknesses of formations in wells drilled in northern Ottawa County.

LOCATION	LEASE	DEPTH	YEAR DRILLED	PRODUCTION
	Mayes County			
NW NE SW 2-19-18	Black and Severson, No. 1	354	1918	Show
SW SW SE 18-19-18	Claver and Dillenbeck, Warner No. 1	783	1926	
NE SW SW 23-19-18	Green, No. 1	622	1925	
NE NW SE 26-19-18	Swingh, Housing No. 1	484	1925	50,000′ gas
SE NW SE 26-19-18	White and Jeffens, No. 1	485	1920	175 bbl. oil
SE SW NE 26-19-18	Sargent, George, Seger, Boyle No. 7	470	1919	1,000,000′ gas
NW SW NW 26-19-18	Campbell and Durto, Boyle No. 2	475	1924	2,000,000′ gas
SW NW NW 26-19-18	Campbell and Rutro, Boyle No. 3	523	1925	1,000,000′ gas
SE NE NE 27-19-18	Campbell and Durto, Boyle No. 1	610	1924	
NW SE NE 27-19-18	Campbell, Polar No. 1	591	1924	1,760,000′ gas
SE SE SW 27-19-18	Swingle, No. 1	605	1925	
NE NE NE 2-20-18	Four Star Oil and Gas, Luttrell No. 1	582	1922	
SW NE NW 8-20-19	J. L. Dixson, Drew No. 1	2395	1927	
NE NE 32-20-19	Layne and Farnsworth, Crockett No. 1	702	1921	
NW NE NE 17-21-18	J. W. Merritt, Price No. 1	615	1928	
SW SW NE 24-21-18	Mayes Oil-Gas Corp., Major No. 1	635	1923	
SW NE SW 30-21-18	Van Nostrand, Swift No. 1	400	1924	
NE NE NW 32-21-18	Van Nostrand, Blake No. 1	440	1924	
SW NW 1-21-19	Invader Oil Corp., Sutte No. 1	795	1924	
NW SW NE 32-21-20	Frank Partain, Sharp No. 1	508	1926	
SE SE SE 9-22-18	A. F. Rose, Plog No. 1	666	1924	
NE NE SW 18-22-18	Rogers Co. Dry Co., Burton No. 1	480	1918	
NE NE NE 4-23-18	Page Oil Co., Robinson No. 2	363	1920	5 bbl. oil
NE NE SE 4-23-18	Page Oil Co., J. Robinson No. 1	389	1920	
NE NE NE 4-23-18	Page Oil Co., J. Robinson No. 3	370	1920	
SE NE SE 4-23-18	Page Oil Co., J. Robinson No. 4	373	1920	

Table showing thicknesses of formations, continued.

LOCATION	LEASE	DEPTH	YEAR DRILLED	PRODUCTION
NE NE SE 2-23-21	J. T. Haggart, Byrn No. 1	1554	1924	
SE SE SE 2-23-21	J. T. Haggart, Byrn No. 2	800	1925	
NW SE SE 2-23-21	J. T. Haggart, Byrn No. 3	555	1925	
	Ottawa County			
SW NE 16-26-23	Fairland City	535	1922	
SW SW 12-27-22	Ottawa County Welfare Home	1055	1928	
	Miami City, Lot 22, Block 7	1257	1919	
NE SE 24-28-22	McCoy's Greenhouse	1046	1926	
NW SW 29-28-22	Bertha McGhee	1500	1914	
SE 25-28-22	Walter Tyding	610	1923	
Picher	Picher City, well No. 3	1098	1924	
NW 21-28-23	Bingham Mine well (Picher City 1)	1077	1920	
NE 19-29-22	Anna Beaver Mine well	1083	1926	
SW NE 25-29-22	Goodeagle Mine well, Hole No. 40	1025	......	
NE NE 25-29-22	B. and R. Mining Co. well	1057	1917	
SW SE 36-29-22	Scammon Hill Mine well	510	1923	
SE NW 16-29-23	Victory Metal Co. well	1025	1919	
NE SE 17-29-23	Lucky Syndicate Mine well	1525	......	
SE NW 18-29-23	Pelican Mine well	1080	1926	
SW SE 19-29-23	Beaver Mine well	1113	......	
NE NE 19-29-24	Rialto Mine well	926	1926	
SE NE 30-29-23	Blue Goose Mine well	1148	1926	

Table showing the thicknesses of formations in wells drilled in northern Ottawa County.

LOCATION	CHEROKEE	MAYES	BOONE	CHATT.	PRE CHATT.
29-28-22	130	25	383	12	950
35-28-22	22	48	390	10	140
12-27-22	60	60	377	15	508
FAIRLAND	.....	10	385	30	35
MIAMI FREENHOUSE	22	35	382	21	586
MIAMI CITY	50	50	382	14	811
25-29-22	103	37	370	5	515
18-29-23	96	35	320	.....	630
17-29-23	90	50	335	5	1045
16-29-23	65	40	370	1	550
19-29-24	.....	.....	370	5	554
SENECA, MO.	.....	.....	270	5	310

OTHER ECONOMIC PRODUCTS

Lead and zinc ore occurs in great abundance in the Boone and Mayes limestone of northern Ottawa County. The ore is found in cavities, fissures, and interstices of flint breccia. There is a bulletin on the lead and zinc district giving complete details of the region now in preparation by the Oklahoma Geological Survey.

Tripoli occurs in the eastern part of Ottawa County adjacent to the Oklahoma-Missouri line, near Seneca, Missouri. Tripoli is a slight weight porous rock originating from weathered flint. The soluble matter present was leached out leaving the flint granules to form the body of the tripoli. The product occurs in the upper part of the Boone and probably in the Mayes formation as well where flint has occurred. The material is used as filter and when ground into powder is used for a high grade metal polish and abrasive. A good description is found in Mining World, vol. 31, no. 11, p. 552, 1909, also Okla. Geol. Survey, Bull. 28.